

## Monitoring the Water Quality in the Recycling Process

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**Abstract.** Specific water contamination requires the recycling process prior to its discharge into the public sewerage network. Electro-flotation technology was used for cleaning of waste water contaminated with the disperse colorants. Dispersion colorants were used to decorate the boxes, made of corrugated board, in the company for the production of packaging. The objective of this paper is to present a method of optimization to determine the length of the time interval for electro-flotation process. Interval should be set so as to achieve the degree of cleaning the water that is the maximum possible in the process of electro-flotation. The measurement of the light passing through the measuring the translucent tube determines the actual degree of the water purity. The measurement is carried out by means of a photodiode in different wavelengths. The measured values in the measuring tube are compared with the nominal value, which corresponds to pure distilled water. Optimization the time interval to clean the water using electro-flotation was determined for yellow color. The optimum interval for the water contaminated with the yellow color was set to 1800s.

### 1. Introduction

Nowadays maintaining the ecosystem requires recycling the waste water with the specific contamination prior to its discharge to the municipal sewage treatment plants. For instance genotoxicity testing of domestic waste prior to its discharge to municipal sewage treatment plants was designated as essential in [3].

Government with its legislative-economic rules also drives the firms toward industrial ecology. To fulfill all the requirements, the company for the packaging production designed the special equipment for treatment the waste water that was contaminated with the dispersion colorants. The dispersion colorants are used for decoration the paper boxes. When cleaning the machines, a huge amount of contaminated water is created. This has created the need to use new, environmentally acceptable and affordable technologies for waste water treatment. The technology of the waste water purifier is based on the flotation process. The sophisticated electronics controls the system from the mixing the waste water with an oxidizing agent to its discharge to the flotation tank. The flotation itself takes place in the flotation tank wherein during the electrolysis reaction; the formed bubbles are associated with particles of the colorant. Electrodialysis is applied as the technology for treatment the water contaminated with the heavy metals [4]. The article [7] deals with the clarification the water in the



rivers of Dnieper basin. Ultrafiltration is used instead of traditional coagulation followed by a mechanical filtration.

During the flotation process, bubbles with the colorant travel toward the surface of the wastewater, where they form foam which is swept at regular time intervals. Flotation as a technology was proved as suitable within the experimental operation, as well as in practice. However the whole process needs monitoring the degree of the water clarification during the flotation process.

There are a few ways how to monitor the water quality or the whole process of the water treatment. Michael Allen with his coauthors in [1] introduces the system of real-time monitoring the amount and quality of drinking water in the distribution infrastructure. Contamination warning based on decision-support system with on-line control was build in collaboration of the The United States Environmental Protection Agency (USEPA) and the towns of state Ohio. Mesi and Kopliku collected water from the surface of the Shkodra Lake in Albania and evaluate the level of contamination that was cost with uncontrolled releases of industrial and urban waste. They used analysis of variance and Student Newman-Keuls (SNK) tests in [5]. Greek editors Kostas Voudouris and Dimitra Voutsas collected in [8] the set of articles devoted to the monitoring the water quality in several countries, especially surface water and groundwater that are the main sources of fresh water for drinking purposes. The water testing is based on the conventional hydrochemical techniques and statistical analysis, such as trend and prediction methods as well as decision support systems with the risk analysis. Authors of different countries illustrate the specific situation with the water sources and assessment of water pollution in their countries. Underwater robot was constructed in [10] to allow more relevant access to the water quality data.

Andrew Moxey collaborated with the experts across OECD member countries on categories related to ecosystem quality and its impact to the human health. Special attention is paid in [6] to agriculture, which is considered to be both environment polluter with the chemicals as well as a victim of pollution. The concentration of polycyclic aromatic hydrocarbons (PAHs) in agricultural topsoil that was contaminated with the wastewater in the particular regions of China is described in [9]. Then correlation was constructed between the irrigation groundwater and topsoil in the levels of contamination. Bhandari and Abrol in [2] discuss their experiences with testing harmful effect of industrial waste water that was discharged as untreated. They used pH electrode (PE03), conductivity electrode ( $k=1$ ), purity sensor and thermistor to check the water properties and subsequently their impact on human as well as aquatic life.

To check the degree of the waste water treatment during the flotation process we decided to use the special equipment based on the photodiode properties.

## 2. Methodology to monitor the degree of the waste water treatment

Monitoring the degree of the waste water treatment is done using the photodiode that is expressed in Figure 1. Figure 1 shows a pipe in which the receiving photodiode is situated on the right. In the middle of the pipe, syringe with a sample of treated wastewater is of enlightened through. The syringe is passed through the opening in the pipe. Placing the pipe is seen in the Figure 3, where the bottom right is a view of the PIN photodiode.

The measurement of the loss of light in different wavelengths is carried out passing the light through the measuring chamber in the shape of the transparent tube. The tube is filled with contaminated water, which is subject to measurement.

The excitation LED powered via a resistor (trimmer would not be sufficiently stable) and resistors are only available in certain values. Therefore the values are not equal, but are sufficiently stable. For example, the voltage of 320mV is determined on the photodiode with the red light from the LED of wavelength 630nm.

The measured values in the measuring tube are compared with the nominal value, which corresponds to pure distilled water as follows:

For wavelength of 950nm (the infrared light), the pure distilled water represents 330mV, what is the voltage on the photodiode, which is loaded with resistor.

Similarly:

for wavelength of 630nm (the red light), the pure distilled water represents 320mV,  
for wavelength of 595nm (orange light), the pure distilled water represents 331mV,  
for wavelength of 580nm (yellow light), the pure distilled water represents 324mV,  
for wavelength of 530nm (green light), the pure distilled water represents 338mV,  
for wavelength of 470nm (blue light), the pure distilled water represents 385mV,  
for wavelength of 400nm (ultraviolet light), the pure distilled water represents 309mV.

In the evaluation of the actual measurement by the human eye, it should be recognized that the change in light transmission of the contaminated water is a logarithmic dependence, that is, the change in value of light transmission of 25% (3 dB decibel) is also detectable with the human eye. That is, if the purity of the solution is higher than 75% of the value measured in pure distilled water, then the human eye does not detect it as dirty, it seems therefore clear. It is therefore necessary to establish the degree of purity of water through precision measuring electronic devices.

The water is stored after purification, by means of flotation, so there is a spontaneous sedimentation that is caused by physical-chemical process of flotation. Thus, a further 48 hours there is completion of the cleaning process, wherein the transparency of treated water is comparable with pure distilled water.

Calibration according to the pure distilled water when measuring the voltage on the photodiode, which is equipped with a working resistor, as well as actual measurements drafts of the contaminated water during its clarification were performed using an accurate digital voltmeter with A / D converter with 24 bit resolution.

Direct measurement using optics directly in the flotation vessel is not possible due to large amounts of microbubbles of oxygen and hydrogen, which arise in the process of electro-flotation. The effect of the bubbles had to be eliminated also after pumping a new sample into the external chamber (Figure 3) to measure in such a way that the sample that has been pumped, has been left to stand for 90s. And also the time interval of the measuring cycle had to be adapted accordingly.

### 3. Equipment description

Figure 1 shows a representation of the measuring light tube, wherein one end comprises an exact insert that is made of textolite as a cover material. Seven pieces of LED, whose wavelengths are indicated in the text, are stored in the cover.



**Figure 1.** Orange LED is active. Transmitted light illuminates into the photodiode.

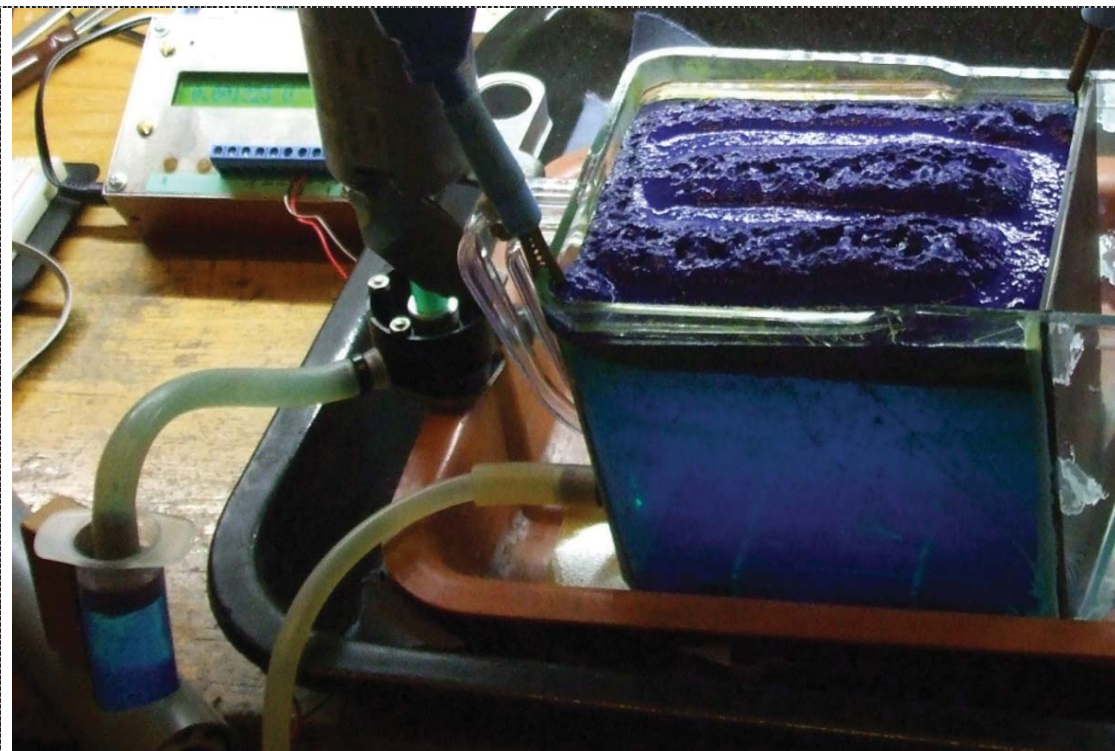
LEDs are positioned so that the axis of the light emitted by them directed in each case exactly into the middle of the opposite insert, which is expressed on the right in the Figure 1. The receiving photodiode PIN type SFH203, which is located in the center of the cover, measures the intensity of the light going from the diode through the transparent measuring chamber shown in Figure 3.

Figure 2 shows also the connection of the device for measuring the water clarity to the flotation vessel. In the center of Figure 3 is seen a modified tubing connected to a syringe. Pumping of the dirty water into the syringe provides engine driving a miniature pump (Figure 2).

Figure 3 shows a view on the attachment of the light measuring tube with photodiode that is shown in Figure 1, to the workbench. In front of the tube is shown receiving photodiode, which is from the back of the shade with the black rubber, to avoid any possible interfering influence of the light from the ambient lighting. Translucent polypropylene tube is inserted vertically into the working tube loophole. The tube is hermetically sealed firmly at the top with plastic insert and connected together using silicone tubing to the flotation container. Purified water is pumped from the flotation vessel in the selected time intervals.

In the middle of Figure 2, the measuring syringe is shown. The syringe is always filled with contaminated water that is measured. The syringe is supported by the small prism so that it keeps the same position. Linking provides the silicone tubing. Below the center of Figure 3 the outlets of photodiode are shown. The photodiode is fixed and it is covered with the rubber ring. Leads are connected to the measurement device to determine the voltage in mV.

The outputs of the photodiode are connected in parallel with load resistor. Thus, it is connected to an electronic measuring system which measures the voltage of the photodiode in mV. Resistor creates a defined load for a photodiode in order to measure the linear light intensity for each LED that means the measurements are possible in the different wavelengths.



**Figure 2.** Connecting the device to measure water purity to the flotation vessel.



Flotation process takes place in a flotation vessel continuously but small pump is used for periodic pumping with measuring tact 150s. The actual pumping to fill the transparent measuring chamber is set to 3s. So the initial solution that was measured prior to 150s is replaced during 3s by a new, cleaner solution from the current flotation vessel. The whole method of measurement is thus constructed so that the original solution prior 150s does not contaminate the new solution for the actual measurement. So the whole process of measurement samples for individual light wavelengths must be done, including reserve of 90s to stabilize the sample, rather than during the 150s, before the drawing of new samples. So it is left for measurement itself up to 60s.



**Figure 3.** Detail of the measurement system.

#### 4. Experimental results and analysis

The results of measurements of voltage, in mV, at the photodiode for the individual wavelengths in the water that is polluted with the dispersion colorant of yellow tone 2201 are shown in Figure 4.

The difference in the degree of water pollution between each measurement was determined as follows:

$$Difference / s = \frac{|LT_{n+1} - LT_n|}{150} \quad (1)$$

where  $LT_i$  means the value of the Light Transmittance [%] that was obtained during the  $i$ -th measurement.

Light Transmittance [%] was set as comparison of the voltage [mV] on photodiode during the measurement of the clarified waste water with the nominal value [mV], which corresponds to clear distilled water.

Statistical method of least squares was used to fit the curve of the Light Transmittance for the individual wavelengths. Least square method is applied using the program product EXCEL with the formula for the index of determination:

$$R^2 = \frac{\sum_{i=1}^n (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \quad (2)$$

where

$y_i$  ... the values of Light Transmittance [%] for the individual wavelengths,

$\hat{y}_i$  ... the functional values for the polynomial of the sixth degree to fit the individual curves,

$\bar{y}$  ... the average of the values Light Transmittance [%] for the individual wavelengths,

$n$  ... number of measurement as amount of the values obtained during the laboratory experiment for the individual wavelengths.

The individual functions to fit the curve:

For the wavelength of 950nm (Figure 5):

$$y = -0.0002x^6 + 0.0101x^5 - 0.2448x^4 + 3.0349x^3 - 20.446x^2 + 72.606x - 25.675 \quad (3)$$

with the value for the index of determination:

$$R^2 = 0.9999$$

For the wavelength of 630nm:

$$y = -0.00002x^6 + 0.0016x^5 - 0.0426x^4 + 0.4176x^3 - 1.3431x^2 + 6.7199x - 4.2717 \quad (4)$$

with the value for the index of determination:

$$R^2 = 0.9994$$

For the wavelength of 595nm (Figure 6):

$$y = -0.00000007x^6 + 0.0009x^5 - 0.0327x^4 + 0.3719x^3 - 1.1952x^2 + 5.3398x - 3.2731 \quad (5)$$

with the value for the index of determination:

$$R^2 = 0.999$$

For the wavelength of 580nm (Figure 7):

$$y = 0.0002x^6 - 0.0095x^5 + 0.1556x^4 - 1.2025x^3 + 5.0441x^2 - 7.9634x + 4.3516 \quad (6)$$

with the value for the index of determination:

$$R^2 = 0.9992$$

For the wavelength of 530nm (Figure 8):

$$y = 0.0001x^6 - 0.0062x^5 + 0.1066x^4 - 0.8375x^3 + 3.4545x^2 - 5.8004x + 3.3307 \quad (7)$$

with the value for the index of determination:

$$R^2 = 0.999$$

For the wavelength of 470nm:

$$y = 0.00005x^6 - 0.0027x^5 + 0.0475x^4 - 0.385x^3 + 1.4921x^2 - 2.5315x + 1.4138 \quad (8)$$

with the value for the index of determination:

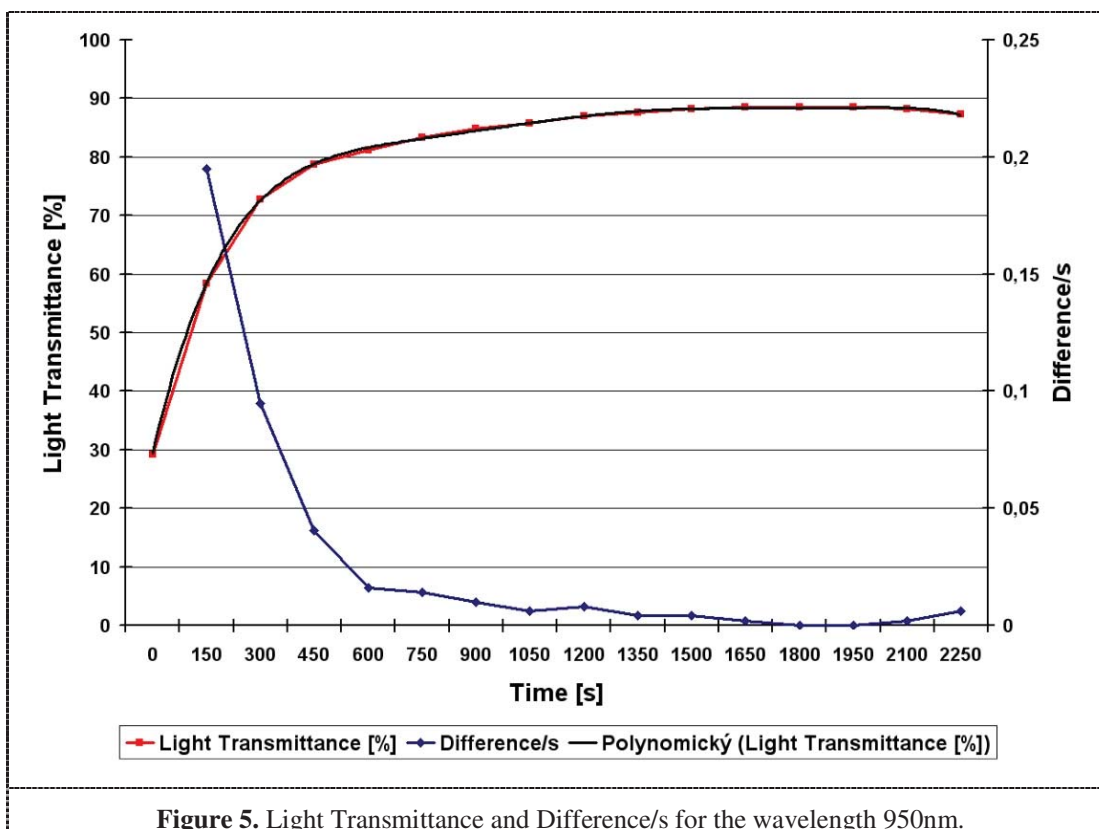
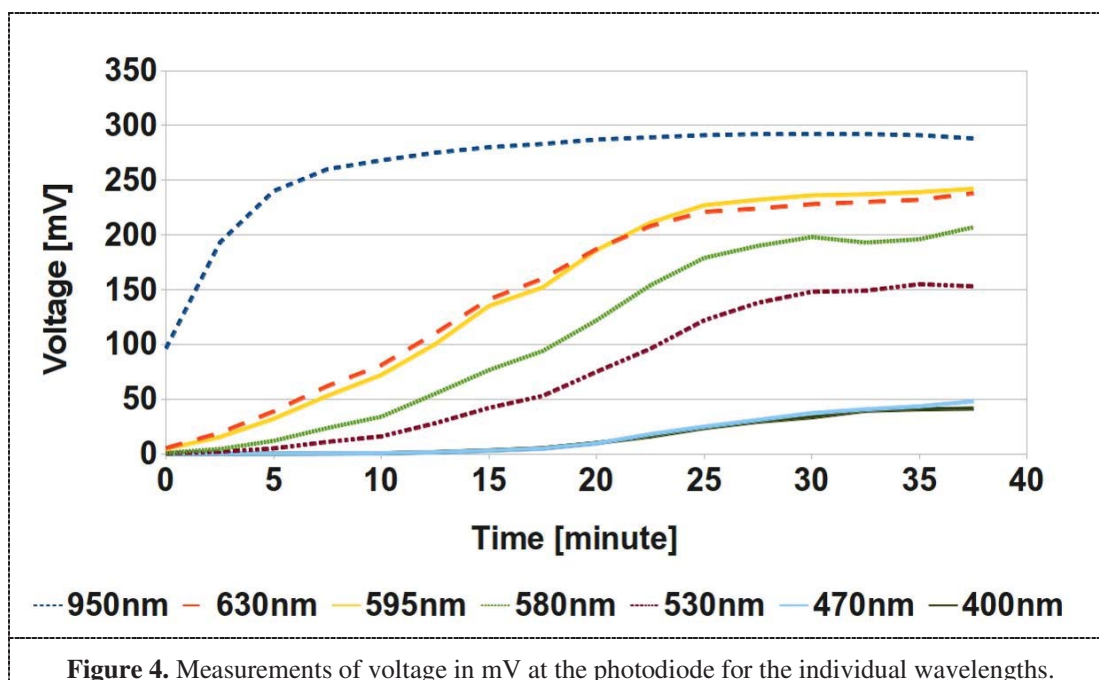
$$R^2 = 0.9993$$

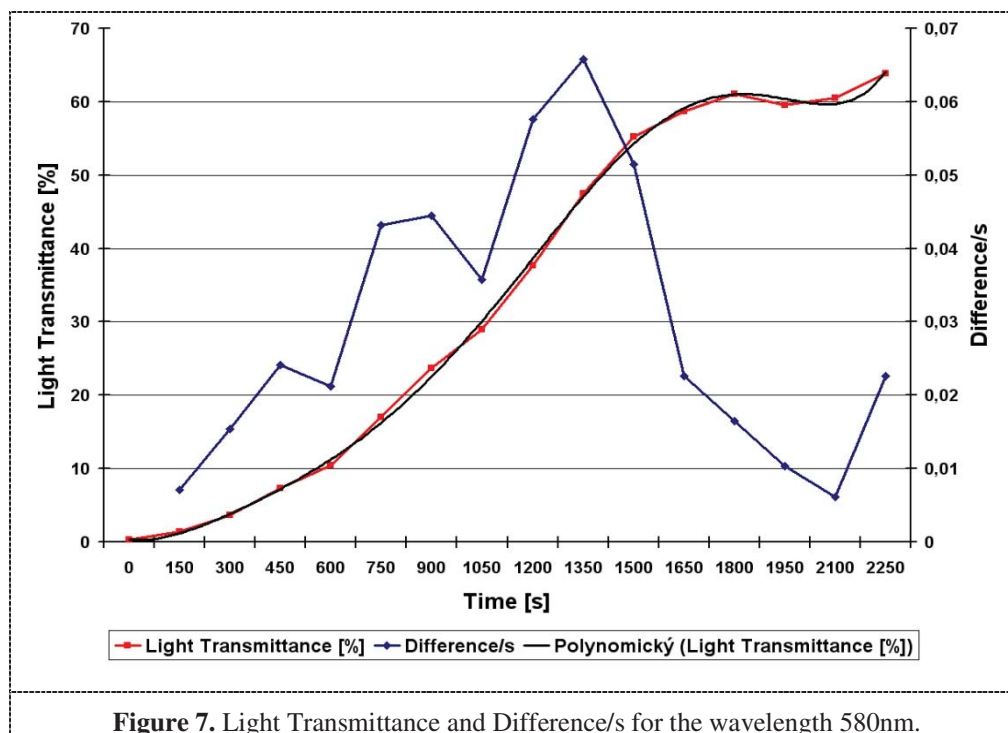
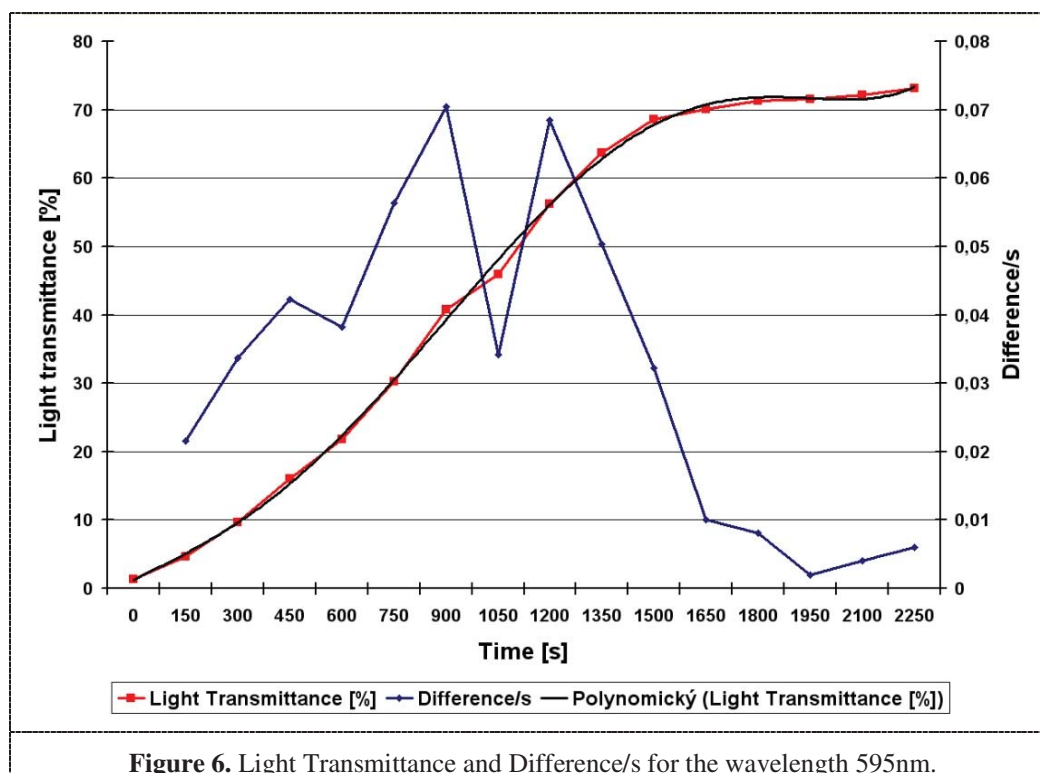
For the wavelength of 400nm:

$$y = 0.00003x^6 - 0.0017x^5 + 0.0308x^4 - 0.2428x^3 + 0.9053x^2 - 1.4636x + 0.7858 \quad (9)$$

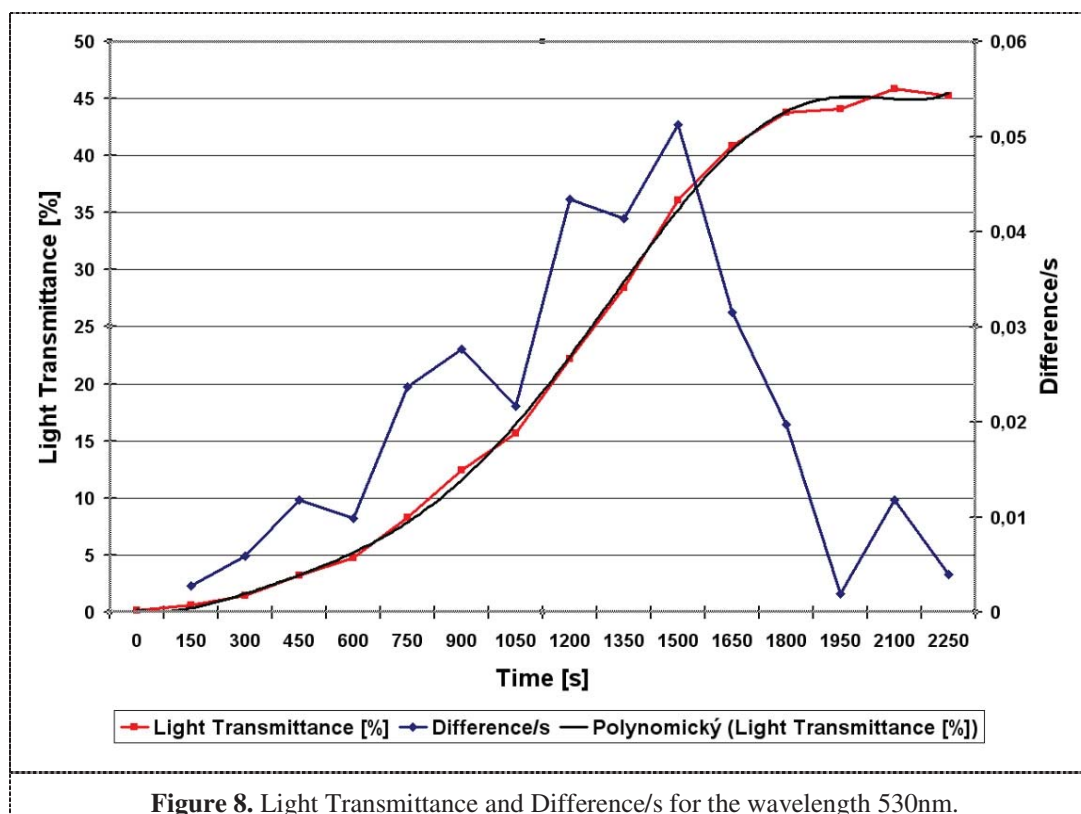
with the value for the index of determination:

$$R^2 = 0.999$$









## 5. Conclusions

The paper presents the technology that has been developed to determine the degree of clarity for contaminated water during the active electro-flotation process so that just the acting electrolytic flotation reaction does not affect the actual measured sample of treated contaminated water nor the measurement process itself. The measurement process for the individual sample must be done during 120s between the insertion of new sample. Determination of Light Transmittance [%] and Difference/s is used to determine the optimal time interval for the maximum possible cleaning of wastewater contaminated with the dispersion colorants in the process of electro-flotation. The water is subsequently clarified by spontaneous sedimentation within the next 48 hours.

Experiments confirmed that the required period of electro flotation depends on the color tone of the dispersion colorant, which caused the water pollution. After this period, which is required for flotation, purity of the water already so clear, that further it cannot be improved more using the same technology. The further improvement the water quality occurs only after a certain time period when spontaneous sedimentation of the water that has already been treated in the flotation process. In practice there is a mixture of different tones colors in the waste water and, therefore, time for the electro-flotation was set to 45 minutes (2700 seconds).

Analysis of the data obtained was performed by application the statistical method of least squares. The optimal time interval for the maximum possible cleaning of waste water contaminated with a yellow dispersion colorant of tone 2201 was set 1800s.

In our following research we will try to determine the optimal time intervals for the maximum possible cleaning up the wastewater contaminated with the dispersion colorants using the electro-flotation technology for variety of colors.

## 6. Acknowledgments

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